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CONCEPTUAL DESIGN OF A MOBILE REMOTE MANIPULATOR SYSTEM

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CONCEPTUAL DESIGN OF A MOBILE REMOTE MANIPULATOR SYSTEM

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July 1984

Space station studies have identified the need for a mobile remote manipulator system (MRMS). Such a logistics or utility device is envisioned to be outfitted with a spacecrane capability (i.e.,- shuttle RMS), and probably astronaut foot restraint positioning arms. The system is required during initial station construction activities to position astronauts for EVA functions, to transport modules and/or payloads from the Shuttle cargo bay and position them for attachment to the truss structure. Subsequent to the initial space station construction activities, a mobile remote manipulator system is considered necessary for maintenance or repair activities, and to provide a construction capability for future station growth or large spacecraft assembly and servicing. The mobile platform which possesses the capabilities described above will be referred to as an MRMS in subsequent paragraphs.

MRMS MOBILITY REQUIREMENTS

The square bay truss structure of the space station configurations shown in reference 1 suggests the need for an MRMS which can move in two orthogonal directions. This capability permits movement (1) along the space station keel structure between the modules and the solar array support structure, and (2) perpendicularly along the solar array support booms. An MRMS with only unidirectional mobility theoretically could be rail mounted to accomplish this function but would probably need to be detached and reattached to additional orthogonal rails to move in a perpendicular direction--an operational drawback which probably should be avoided. Mounting rails onto the space station truss structure introduces additional mass and significant design complexity which also must be considered.

The lower mass alternative of positioning rails on the MRMS (instead of the truss) which "ride" on the truss hard points is possible. However, endless tracks (chains or belts) which provide mobility in this case must completely span two (2) truss bays to ensure stability of the MRMS during motion. Such an arrangement avoids the increased mass and complexity of rails attached to the truss structure and provides for a "smooth," continuous unidirectional motion capability. However, movement in a perpendicular direction is not enhanced, and the undesirable feature of an MRMS which must be two (2) bays in length is introduced. A two-bay-long MRMS presents Shuttle packaging problems and degrades maneuverability and, therefore, usefulness for maintenance and construction activities, particularly in close proximity to the modular habitats or surface attached equipment.

A robotic walker ("spider") conceptually could serve as an MRMS and accomplish the necessary functions, but would require extensive development of a device which is not considered state-of-the-art.

REFERENCE MRMS DESIGN

A conceptual design for a bidirectional MRMS which is only one-bay square and avoids a truss mounted rail system is illustrated in figure 1. This design, which is a modification of a two bay long device described in reference 1, consists of three basic elements or layers. The bottom or track layer consists of a square track arrangement which rides on structural guide pins attached to the truss nodes. The four (4) tracks are arranged in a single plane and connected at the corners by "switches" which can be aligned to permit motion over the guide pins in either of two orthogonal directions (see figure 2). The track layer does not rotate relative to the truss structure. The four corner switches rotate 90° but only when centered over the guide pins.

The central element consists of a push/pull drive mechanism which also has 360° rotation capability (see figure 3). This feature permits platform movement in four directions by either a push or pull operation and greatly enhances maneuverability without requiring additional structure for translation. It also permits changing movement direction without rotating the logistics platform (e.g.,- attached payloads). The push/pull motion is envisioned to be powered by an electric stepper motor through a rack and pinion drive. Mounted on the drawbar ends are "drive" rods which are aligned with, and electrically inserted into, the nodal guide pins and locked. The switches are aligned appropriately and the drawbar is actuated to push or pull the MRMS in the desired direction. The drawbar extends to span a complete bay, such that four point support of the MRMS is maintained at all times. Translation of the MRMS is accomplished by operation of the push/pull drive mechanism to move the platform longitudinally in an "inch-worm" fashion. This sequence of events is illustrated in the upper half of figure 4. Transerse translation involves use of the pivoting, as well as push/pull feature of the mechanism, and is illustrated in the lower half of figure 4. Sketch (A) shows the MRMS pivoting 90° from the direction of travel. Sketch (B) shows a translation to construct an adjacent truss cell which is in the next row. Sketch (C) shows the MRMS sliding onto the cell just constructed. Sketch (D) shows a 90° rotation into a position parallel, but on an adjacent row, to the original. Sketches (E) and (F) show longitudinal motion and construction of added cells to complete a platform. The corner switch illustrated in figure 5 shows the open top mechanism feature which permits the drawbar to lock onto a guide pin which is also occupied by a track switch.

The top element of the MRMS is the logistics platform which is envisioned to rotate with respect to either the track or drive elements (see figure 6). This platform would serve to transport payloads and cargo over the space station surface. A central feature of this element would be the capability to operate a transposed Shuttle RMS, which is shown in figure 6 mounted on a moving carriage. Also shown in figure 6 are mobile foot restraint (MFR) positioning arms. Pressure suited astronauts attached to the MFR's are positioned within their work envelope by the movable positioning arms in a manner similar to reference 2. The MFR arms should not be considered to be miniature versions of the Shuttle RMS, with its precedent setting precision control requirements. Rather, each MFR arm should be controllable by the astronaut who can adjust its position in a manner similar to a utility serviceman operating a "cherry picker" bucket. The degrees of freedom required by the MFR arms are determined by the extent to which EVA is utilized to perform various future space station functions.

The MRMS should have a self contained, rechargeable power supply which does not require umbilicals or power rails. Control of all features of the MRMS should reside with the EVA astronaut(s) to avoid hardline or RS control links to a central station. Transport cradles or similar devices must be provided to support payloads being moved about the space station surface by the MRMS.

MRMS PLANE CHANGE CONCEPT

The proposed MRMS can operate over both the "top" or "bottom" surfaces of the reference configuration, if required, using the rotary joints and solar array boom rotation as a turntable to translate between the two parallel surfaces. For generality and versatility, however, it is desired to operate the MRMS in a plane which is perpendicular to these parallel surfaces. Two (2) concepts for rotating the operational plane of the MRMS 90° from its original position are shown in Figures 7a and 7b. The concept shown in Figure 7a uses a tilting frame approach to rotate the MRMS 90° and enable translation and operation onto a perpendicular plane. The tilting mechanism is envisioned to be self-contained and installed as a truss cell unit into a beam or along a platform edge. This unit should be capable of rotating 90° in both the "left" or "right" hand directions.

A second approach is illustrated in Figure 7b which is operationally more complex but mechanically simpler and probably more compact than that of Figure 7a. This concept consists of a planar guide pin frame which is attached to the original structure at the center of an element which replaces a truss strut. A center section of this element contains a "T" fitting which has two perpendicular rotational degrees of freedom. Operationally, the MRMS translates laterally onto the attached guide pin frame. The MRMS and frame are then rotated 180° around the frame centerline attachment as shown in Figure 7b into an "upside down position." The MRMS and frame are then rotated 90° around the strut element centerline to a position which permits the MRMS to translate onto the plane which is perpendicular to its original operational plane.

Two devices, such as those just discussed or another appropriate design, placed in opposite faces of the truss structure would permit more rapid and convenient translation of the MRMS between "top" and "bottom" surfaces of the station rather than interrupting the rotation of the solar wing for this purpose.

CONCLUDING REMARKS

A conceptual design for a mobile remote manipulator system has been presented. This concept does not require continuous rails for mobility (only guide pins at truss hardpoints) and is very compact being only one bay square. The MRMS proposed is highly maneuverable being able to move in any direction along the orthogonal guide pin array under complete control at all times. The proposed concept would greatly enhance the safety and operational capabilities of astronauts performing EVA functions such as structural assembly, payload transport and attachment, space station maintenance, repair or modification, and future spacecraft constructions as servicing.

The MRMS drive system conceptual design presented is a reasonably simple mechanical device which can be designed to exhibit high reliability. The Shuttle RMS is a developed system, which only needs minor modification to permit its installation and operation from a mobile base. The MFR positioning arms are not envisioned to need the precision control capability of the RMS. Developmentally, all components of the proposed MRMS either exist, or are considered to be completely state-of-the-art designs requiring minimal development--features which should enhance reliability and minimize costs.

REFERENCES

1. Mikulas, Martin M., Jr.; Bush, Harold G.; Wallsom, Richard E.; Dorsey, John T.; and Rhodes, Marvin D.: A Manned-Machine Space Station Construction Concept. NASA TM 85762, February 1984.

2. Heard, Walter L., Jr.; Bush, Harold G.; Wallsom, Richard E.; and Jensen, J. Kermit: A Mobile Work Station Concept for Mechanically Aid Astronaut Assembly of Large Space Trusses. NASA TP 2108, March 1983.

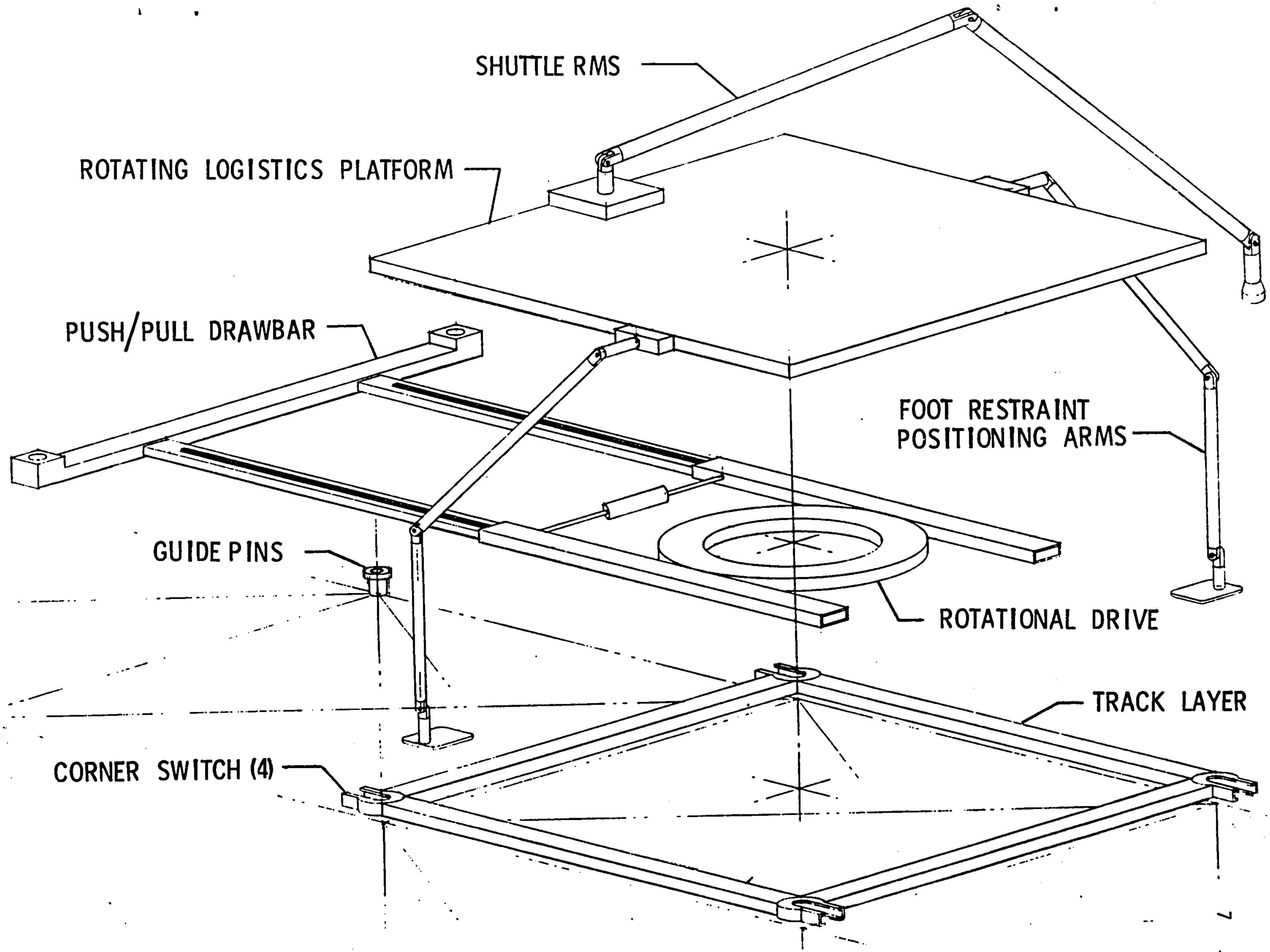

Figure 1.- Mobile Remote Manipulator System Elements (Exploded View)

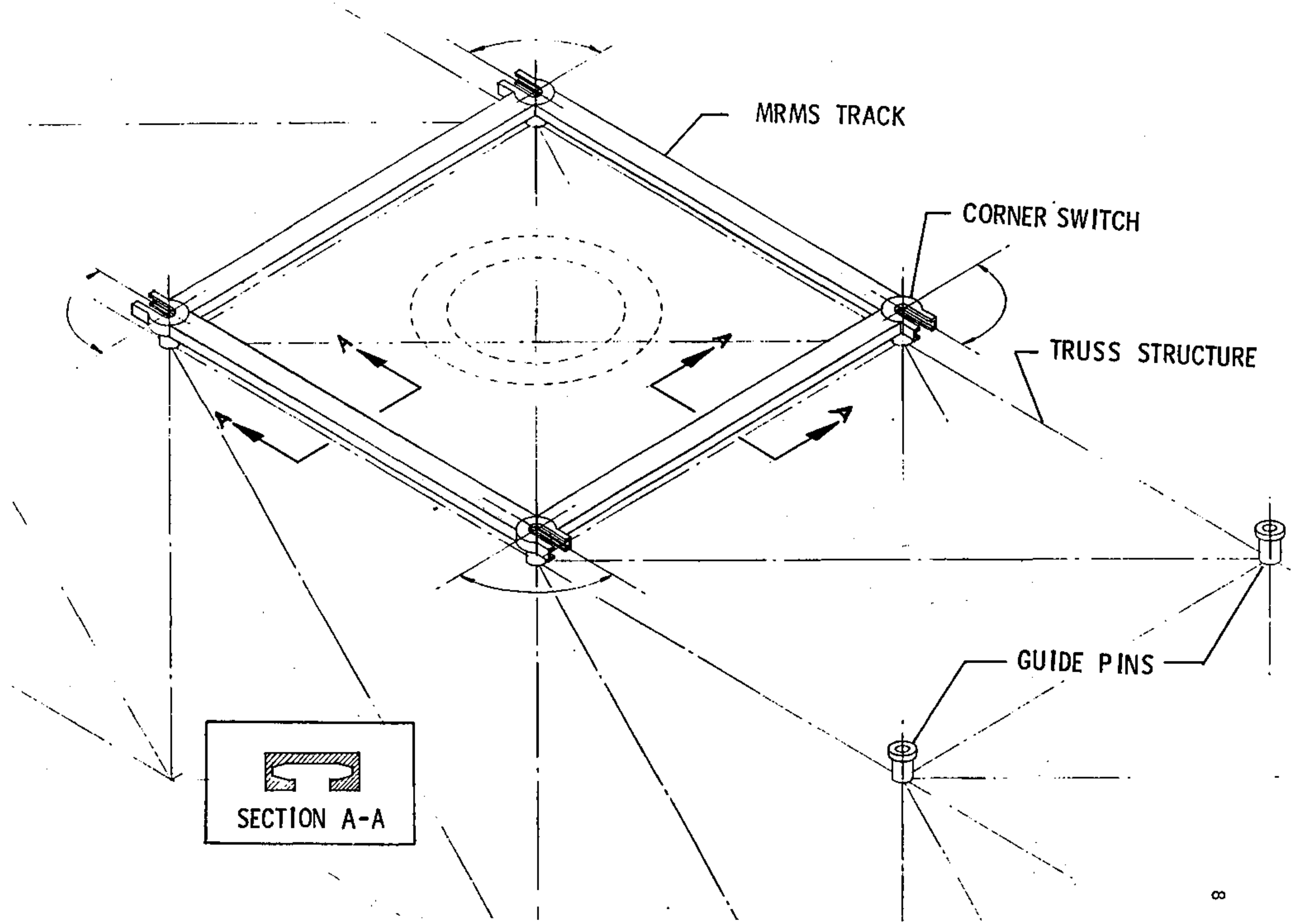

Figure 2.- Track and Corner Switch Arrangement

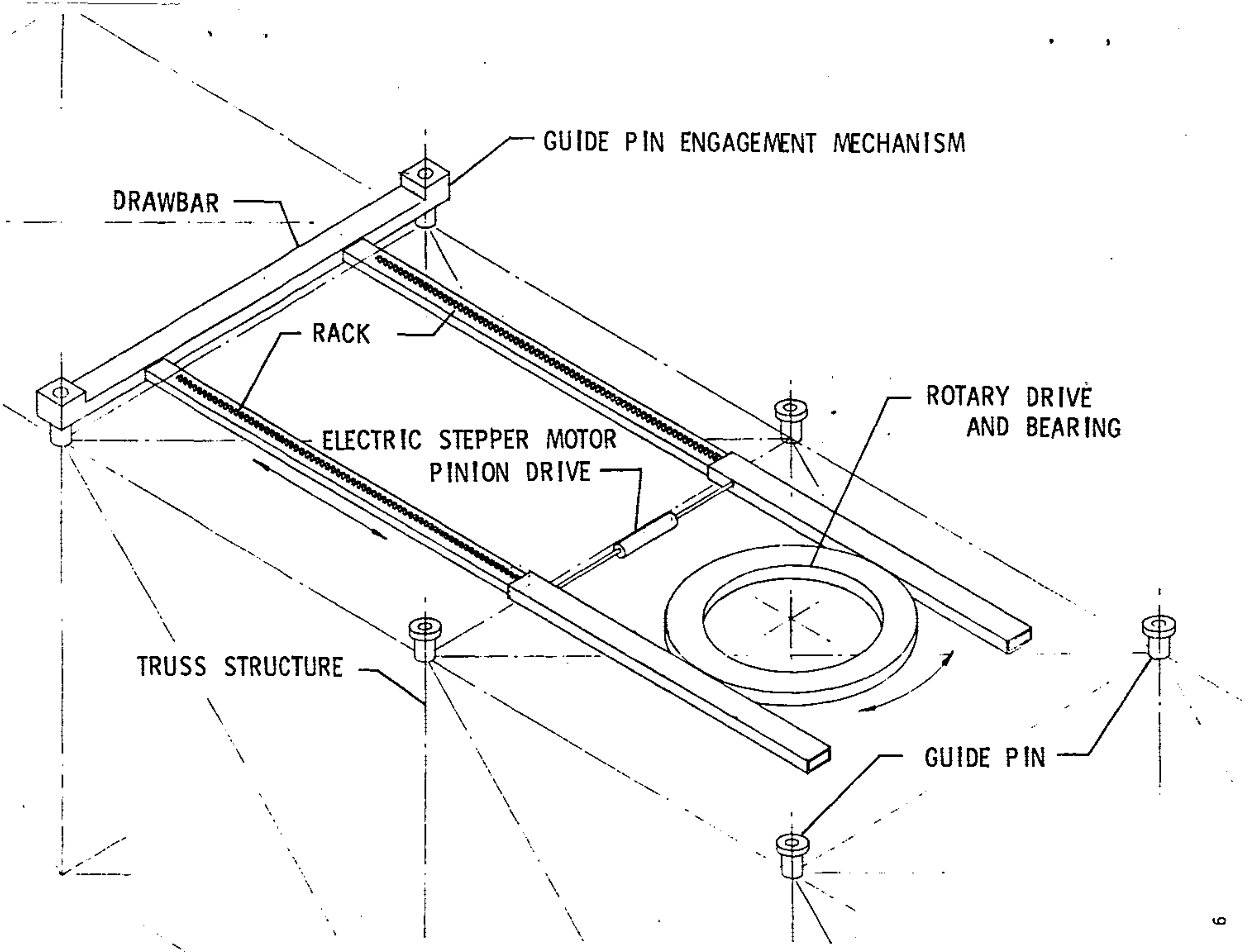

Figure 3.- Push/Pull Drive System Arrangement

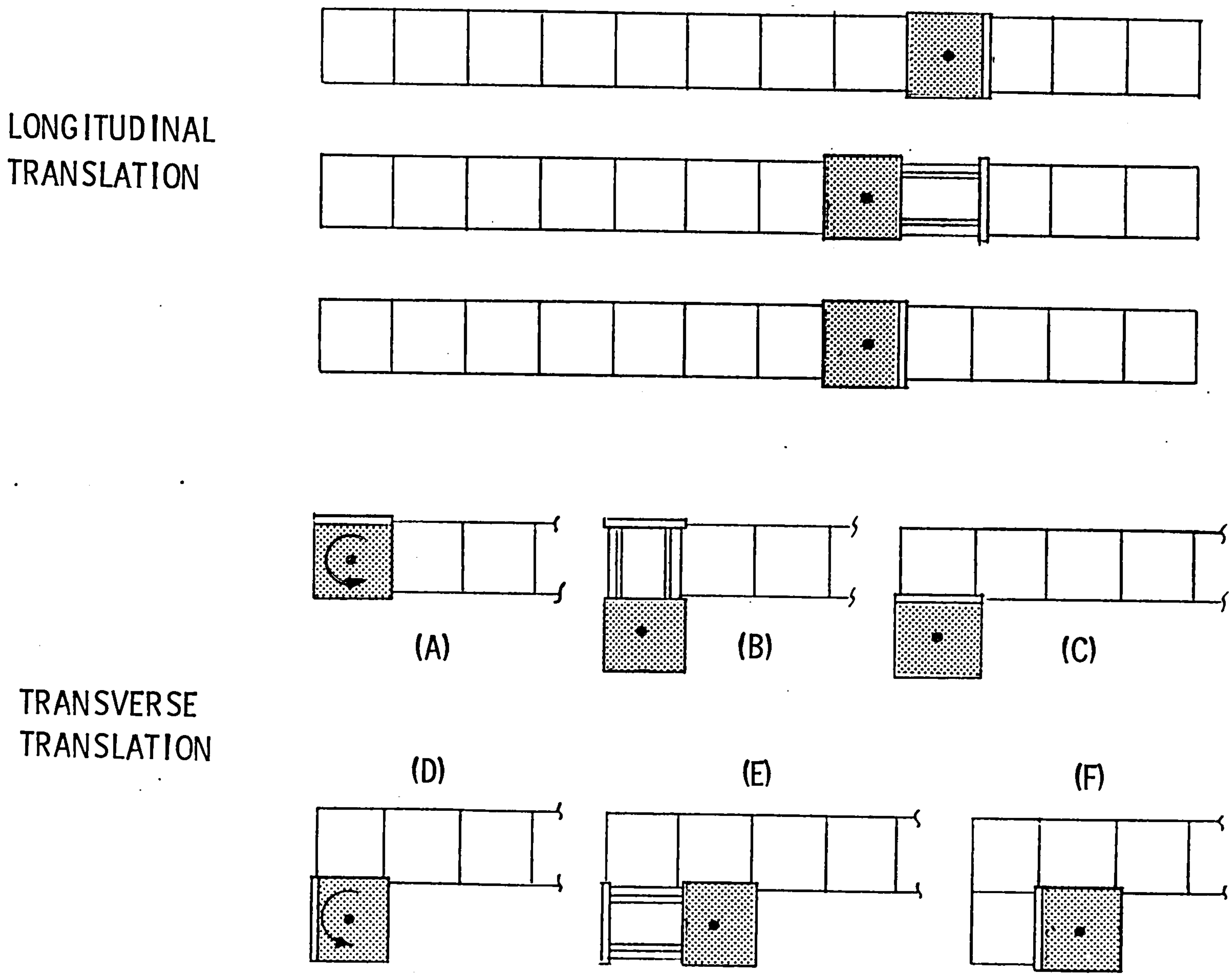

Figure 4.- Mobile Remote Manipulator System Translation

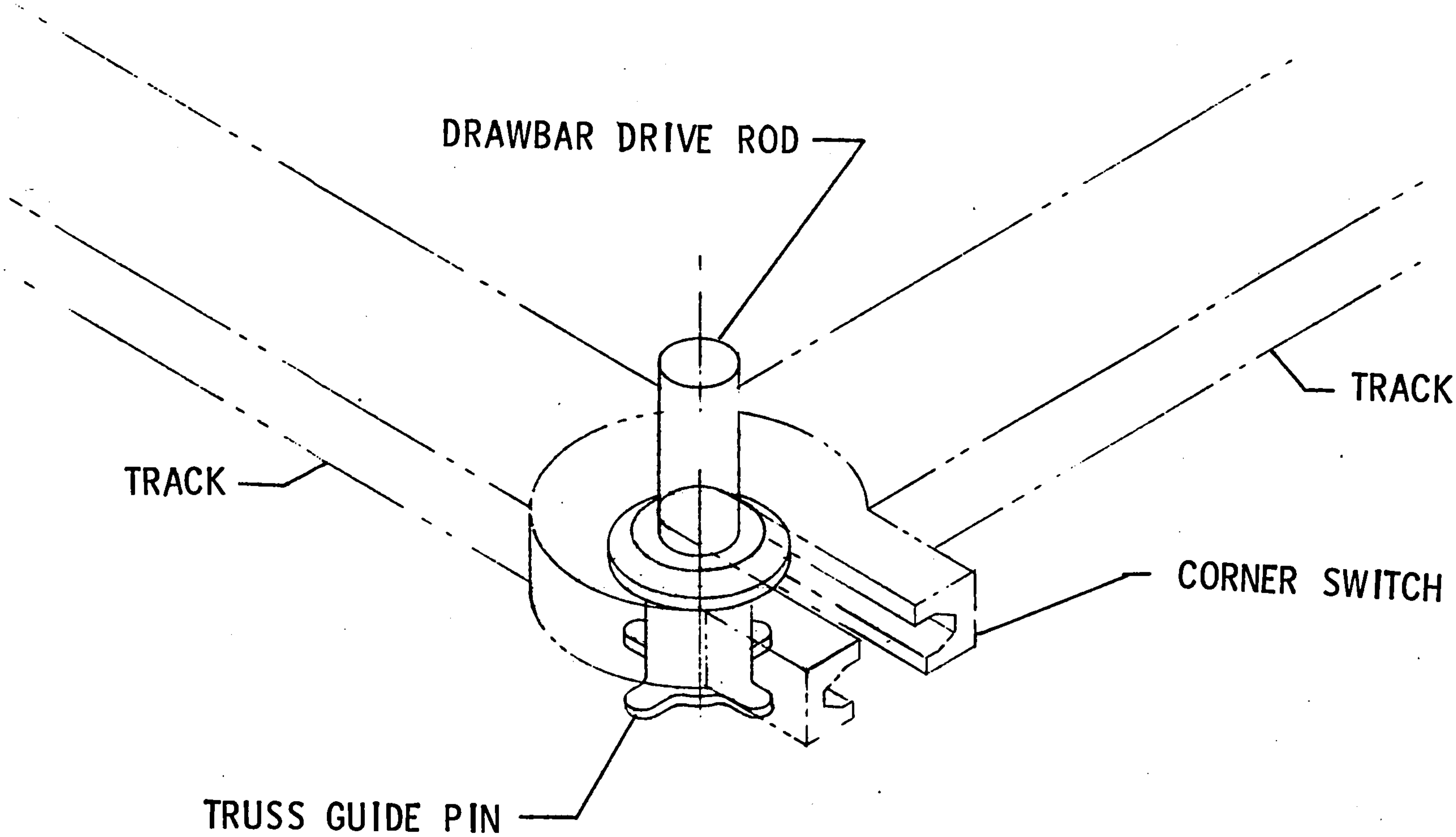

Figure 5.- Corner Switch, Guide Pin, and Drive Rod Arrangement.

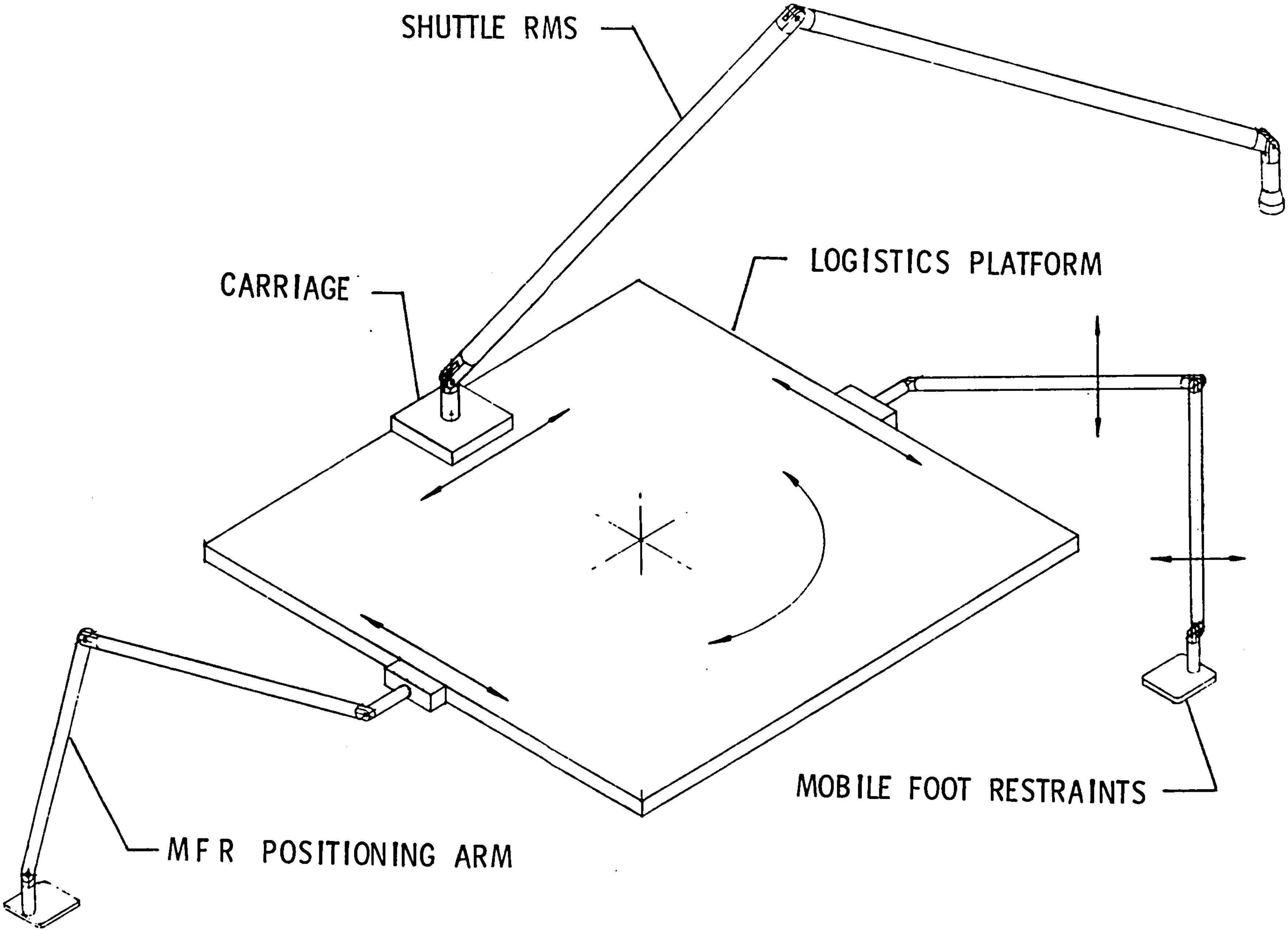

Figure 6.- Remote Manipulator and MFR Positioning Arm Arrangement

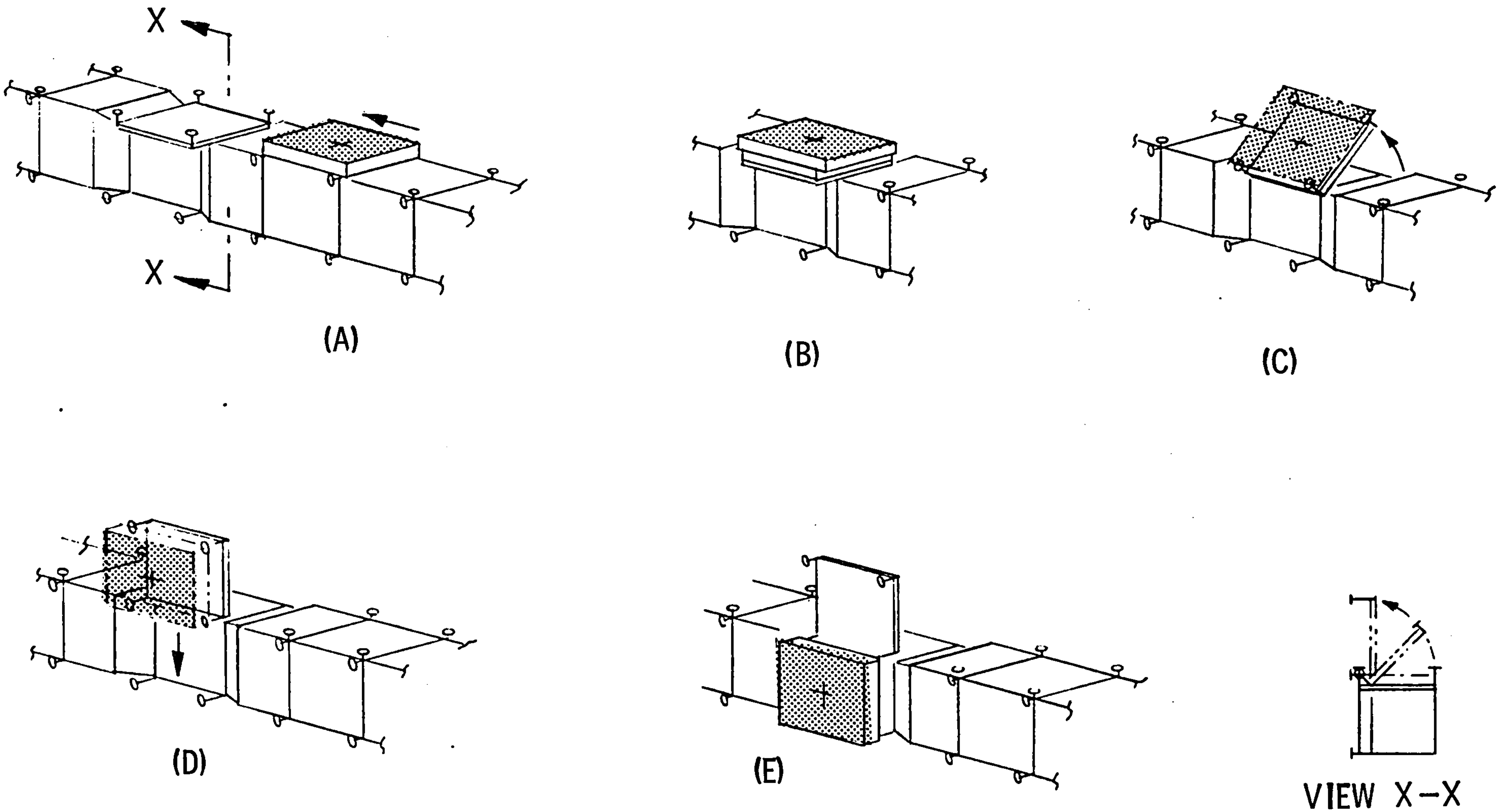

Figure 7a.- MRMS Operational Plane Change-Concept I

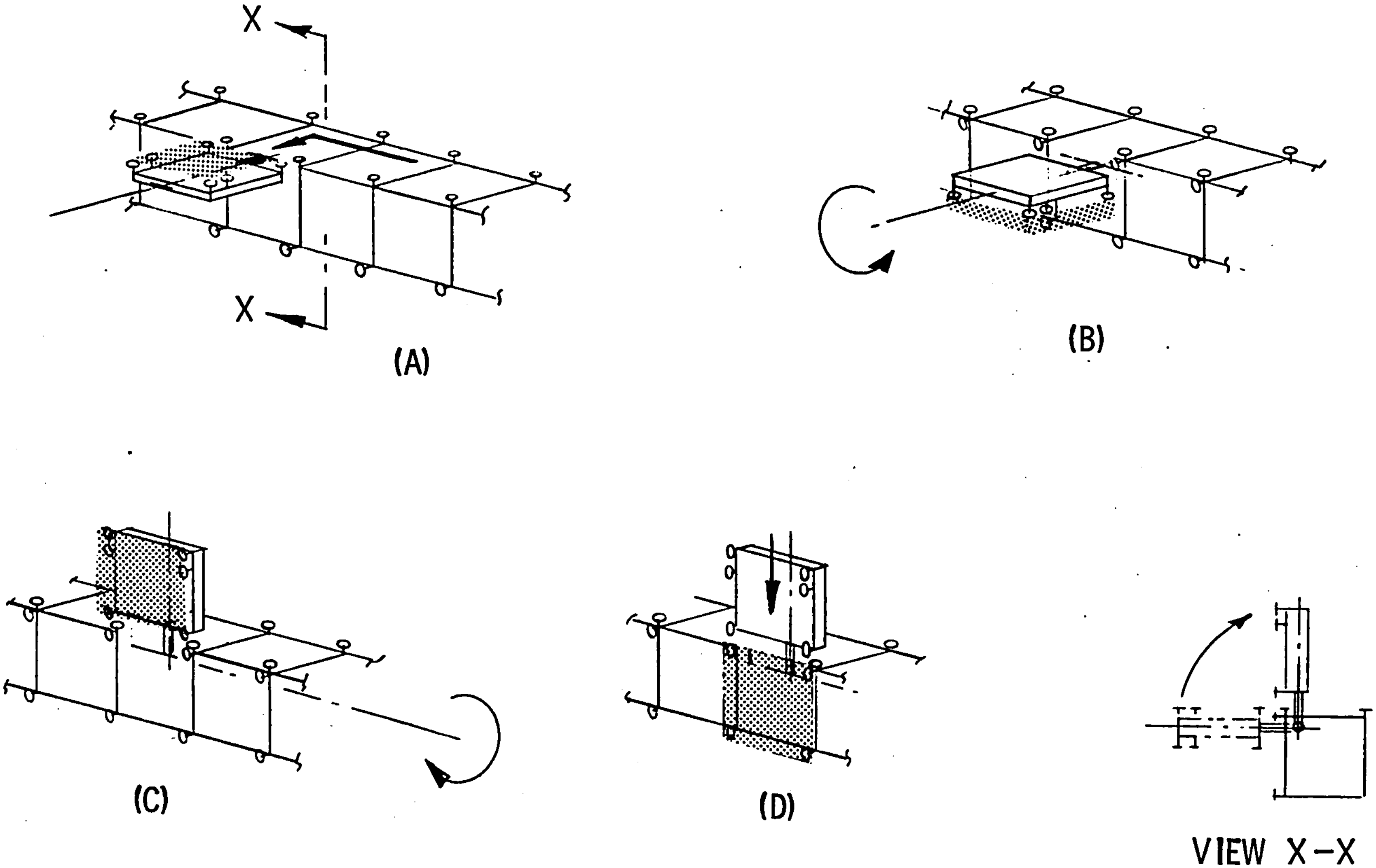

Figure 7b.- MRMS Operational Plane Change-Concept II

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15. Supplementary Notes

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16. Abstract

A mobile remote manipulator system has been identified as a necessary device for space station. A conceptual design for an MRMS is presented which features (a) tracks on the MRMS and guide pins only on the truss structure, (b) a push/pull drive mechanism which rotates to permit movement in four directions, and (c) spacecrane and mobile foot restraint manipulators (or arms). Operational and design features of the MRMS elements are described and illustrated. Concepts are also presented which permit rotating the operational plane of the MRMS through 90°. Such a system has been found to have great utility for initial space station construction, maintenance and repair, and to provide a construction capability for future station growth or large spacecraft assembly and/or servicing.

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